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IDENTIFYING CARDIOVASCULAR AND EYE DISEASES USING RETINAL VESSEL AND OD SEGMENTATION

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Abstract - Retina is responsible for capturing the visual and triggers the nerve impulses in the brain. Retina is related to heart through the blood vessels which are connected to the arteries and veins in the heart. Blood vessels in the retina reflect the changes in the blood vessels of other parts of body like heart, brain, kidney etc., The six largest arteries and veins are measured using CRAE and CRVE which have strong correlation with stroke and heart diseases. Thus wrong identification of vessels leads to wrong diagnosis. Hence a post-processing step is introduced to vascular segmentation for identifying the true vessels. It models the segmented vascular structure as a vessel segment graph and the problem is formulated as finding the optimal forest. In addition to finding the cardio-vascular disease, in the proposed work, glaucoma disease is also identified. It identifies the various eye related infection by just segmenting the optical disk and cup using medial axis detection and vessel bends detection. It implements the cup boundary algorithm to find the cup to disk ratio. Based on this ratio the type of eye disease is detected.

***Keywords* -** Vessel segment graph, CRAE, CRVE, post-processing, segmentation, vascular structure

I. INTRODUCTION

Biomedical engineering (BME) is the application of engineering principles and design concepts to medicine and biology for healthcare purposes e.g. diagnostic or therapeutic. This field seeks to close the gap between engineering and medicine: It combines the design and problem solving skills of engineering with medical and biological sciences to advance healthcare treatment, including diagnosis, monitoring, and therapy.

Retinal images have the potential to facilitate early detection of retinal pathologies. Blood vessels can be visualized directly in the retina. The retina is a layered tissue lining the interior of the eye that enables the conversion of incoming light into a neural signal that is suitable for further processing in the visual cortex of the brain. The diseases that could affect retina such as diabetic retinopathy from diabetes, the second most common cause of blindness in the developed world, hypertensive retinopathy [16] from cardiovascular disease, and multiple sclerosis.

Glaucoma is a serious disorder that affects the visual loss. It is considered as a progressive degeneration of the optic nerve. Optic Disk (OD) in retina is responsible for the visual information transmission from the photo receptor cells to the brain. OD consists of cup region and a Neuroretinal Rim. Glaucoma detection in the proposed work is used as a pre-screening tool for diabetic Retinopathy using the OD and cup diameter, rim area and mean cup depth.

Various methods are used to detect the cup boundary using the vessel bends and the intensity of the images. In proposed work, cup to disk ratio (CDR) is calculated and based on the CDR, severity levels of eye is detected and prevents the visual loss.

II. METHOD

The method for finding all the true vessels includes a novel technique that performs the vessel segmentation using the fuzzy segmentation and uses the median filter to remove the noise before segmentation. After segmentation it implements the graph tracer algorithm to identify true vessels by tracking all the crossover points in the vessel and applies CRAE and CRVE measurements to the six large arteries for identifying cardiovascular disease.

***Graph Tracer* -** In this method vessels are arranged in a binary tree and it identifies all the crossovers and optimal forest [1] is searched from the binary tree.

Glaucoma Assessment – Additionally medial axis detection and 2D Spline interpolation algorithm is implemented to segment cup and Optical Disk in order to find glaucoma affection.

The FCM (Fuzzy C-Means) algorithm [14] attempts to partition a finite collection of n elements into a collection of c fuzzy clusters with respect to some given criterion. Given a finite set of data, the algorithm returns a list of c cluster centers and a partition matrix, where each element wij tells the degree to which element xi belongs to cluster cj.

III GRAPH TRACER

Graph Tracer Algorithm [1] aims to identify vessels from vessel segmentation and represented in binary trees for subsequent vessel measurements. It has two main steps: To 1) Identify crossovers 2) Search for the optimal forest set of vessel trees. Various Keys to identify crossovers are as follows.

A) Crossover segment: It occurs when two different vessels share a segment.

B) Crossover Point: Given the set of white pixels *P* in a line image, a junction $J \in JP$ is a crossover point if and only if the number of segments that are adjacent to *J* is than or equal to 4 cross (J) is true iff $|\{s \in SP\ |adj(s, J)\}| \geq 4$.

C) Directional Change Between Segments: The directional change between the two segments is given by the calculation, $\Delta D(sa,sb)=\cos-1(va\cdot vb)/(|va||vb|)$, where $\Delta D(sa,sb) \in [0^\circ, 180^\circ]$. When the directional change is minimal i.e., <30 degree it is considered as a bifurcation else it is considered as a crossover

Graph tracer algorithm models the segments as a segment graph and use constraint optimization to search for the best set of vessel trees from the graph. A binary tree is a natural representation of an actual blood vessel as it only bifurcates. Segment end points near the inner circle of the zone of interest are automatically identified as root pixels. The identified crossover segments in Fig. 1 are represented as binary tree as in Fig. 2.

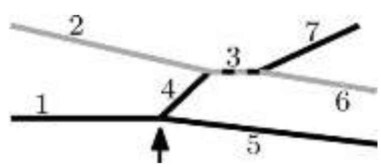

Fig. 1 Identification of crossover segments

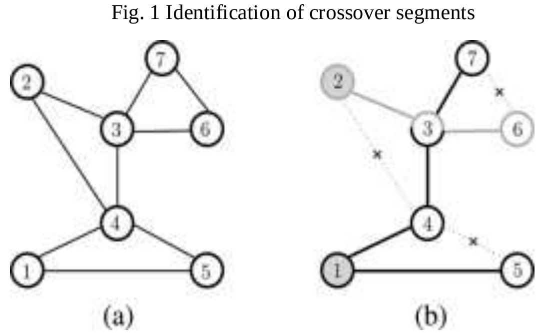

Fig. 2 Segment graph corresponding to the segments and forest of two binary trees

It formulates the problem of finding the optimal forest as a Cost optimization problem (COP). Graph tracer algorithm solves the COP by computing the minimum cost on the forest using the Lower bond cost. It performs as follows: 1) Checks whether the cost of the forest is minimum comparing the corresponding cost. 2) Updates the cost of the forest if it is minimal else goes to step 3. 3) If cost is not minimal it prunes the descendant forest. 4) It then finds the number of children and pushes the child nodes to the stack. 5) Once there are no children available it pops the tree and analyze the cost.

IV GLAUCOMA DETECTION

Even though the graph tracer algorithm identifies vessels simultaneously there are certain limitations such as follows: It considers all the individual vessels for medical diagnosis, and it didn't consider glaucoma diagnosis which may result in wrong diagnosis of disease.

Hence in addition to finding the cardio – vascular diseases, a special technique is introduced to find the glaucoma diseases that it helps in early detection of the eye related infections. It uses the special cup and OD (Optical Disk) segmentation using the cup boundary algorithm which uses the cup to disk ratio for assessment. Since enlargement of the cup with respect to OD is an important indicator of glaucoma progression, various parameters has been estimated and recorded to assess the glaucoma stage.

A) OD Segmentation

There are various methods for segmenting Optic Disk and they are as follows: In shape based template matching OD is considered as an elliptical object and the matching is done on the edge map. But it is difficult to find vessel edges in and around the Optic Disk. Gradient based Active contour model obtains the shape irregularity and finds the deformation in the disk by initializing contours. The proposed work uses the Region based approach which is an enhancement of the C-V [19] model. It operates in two steps:

1) Localize OD and Initialize Contour where it extracts the Region of Interest and selects the OD center and the radius is taken as the edges near the center
2) Segmentation in OD where it uses the Gaussian filters responses at 2, $\sqrt{2}$, $2\sqrt{2}$ and represents the images in 3 elements to capture the irregularity.

B) Cup Segmentation

Previous methods for the cup segmentation obtained set of pixels from a cup region and used an ellipse to fit these pixels to obtain the cup boundary. The cup segmentation method follows the steps as in Fig. 3.

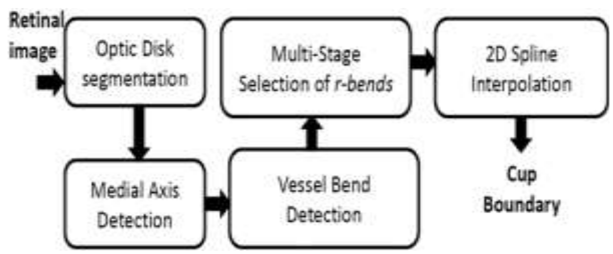

Fig. 3 Cup segmentation method

The proposed cup segmentation uses the vessel bends to mark the cup boundary and is identified by the direction change in vessel pixels. It includes the following steps:

1) Medial Axis Detection

Since the OD comprises of both thick and thin vessels blood vessels are detected as Trenches. Trenches are the regions characterized by high curvature points. A point is a trench when the maximum response calculated is higher than the threshold. It uses 2-phase thresholding where pixels are categorized as 2 sets based on the application of higher and lower value to vessel points. The final trench points include the points in the set 2 which is connected to set 1 and is more precise.

2) Detection of Vessel Bend

It detects the corner point as in [21] by using the Region Of Support scheme (ROS). First it extracts the vessel segments, and then it computes the 1D curvature profile and locates local maxima which are the candidate set of bends. Then the bend is found by calculating the angle between line joining bend and centers of mass on either sides of ROS. Bends above 170 degree are eliminated since it crosses the cup region.

3) Multi – Stage selection of r-bends

R-bends are identified by two points P – where the points within pallor region.

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The location of the bends is denoted by b and is localized by best fit circle. Bends in the circle are sent to the next stage. In Fine Selection sector wise location are used to analyze the bends. Vertical and horizontal vessels are categorized as Sec 1&3, Sec 2&4 and are retained with step size of 20 degree as in Algorithm 1.

Algorithm 1 Multi-Stage selection of *r-bends*

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Coarse Selection: Fit a circle to the set of candidate bends b_i and bright pixels in the pallor region
Select the bends which lie in the vicinity of this circle for the next stage
Fine Selection: Classify the bends into two categories: a) sector 1&3, b) sector 2&4
Compute the parent vessel-segment orientation bθi for each bend b_i
Scan each sector in steps of 20°
if Bend(s) exist then
if bθi is correct then
if multiple then
Select r-bend with least bend angle
else
Select r-bend
end if
end if
else
continue
end
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4) 2D Spline Interpolation

It chooses a local, cubic cardinal spline with the shape parameter t which controls the bending behavior. It is used to approximate the cup boundary where r-bends are absent.

Finally, the CDR is calculated by counting total number of pixels in the optic cup and optic disc, the cup to disc ratio can be calculated by taking the ratio of the number of pixels in the optic cup to number of pixels in the optic disc. The CDR is 0.3 for normal images. If it exceeds 0.3 glaucoma is present. The higher the cup to disc ratio, higher the severity level of glaucoma.

V EXPERIMENTS AND RESULTS

Several datasets have been taken and experimented for detecting the glaucoma and cardiovascular risk

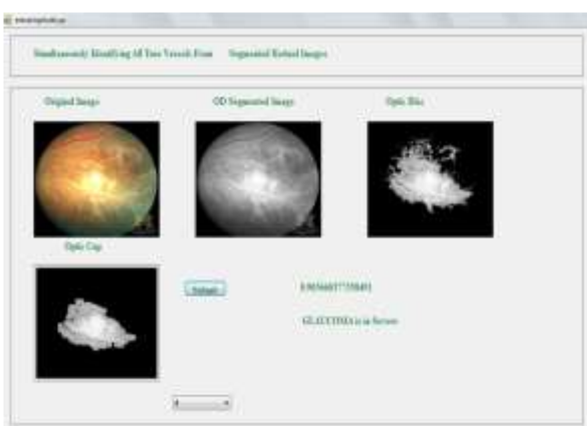

Fig. 4 a) Earlier glaucoma stage with medium CDR

Fig. 4 b) severely affected eye with high CDR

Fig. 5 a) Artery and Vein count showing no risk

As shown in Fig 4 glaucoma is detected in three stages as normal, medium for showing earlier stage of glaucoma and the severe affection which will lead to prevent the visual loss.

Fig. 5 b) Artery and Vein count showing Hypertension

Also, the cardiovascular risks are experimented and shown in Fig 5.

VI CONCLUSION

Retinal vascular structure measurements provide good diagnostic capabilities for the risk of cardiovascular diseases. The wrong identification of vessels will lead to incorrect diagnosis. In the existing System Dijsktra, Solo tracer and Graph Tracer Algorithm used many segmentation methods to identify the true vessels. Graph tracer simultaneously identified the true vessels which are measured against CRAE and CRVE measurements to detect the cardiovascular risks. But it needs to consider all the vessels for identification. A new approach for the automatic detection of the optic disc is introduced for glaucoma assessment. The proposed algorithm will focus on the use of a new grey image as input obtained through LDA which combines the most significant information of the three RGB components. Several operations based on the mathematical morphology have been implemented with the aim of locating the OD. The new system employs cup and optic disk segmentation using medial axis and vessel bends detection. Early diagnosis of the glaucoma prevents visual loss.
The proposed work will be extended to detect the exudates in order to diagnose diabetes using Optic Disk in future and will estimate the age of the patient with the CRAE and CRVE measure.

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